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CLINICAL AND EXPERIMENTAL STUDY ON THE POSTURE AND MOVE MENT IN CEREBRAL PALSY

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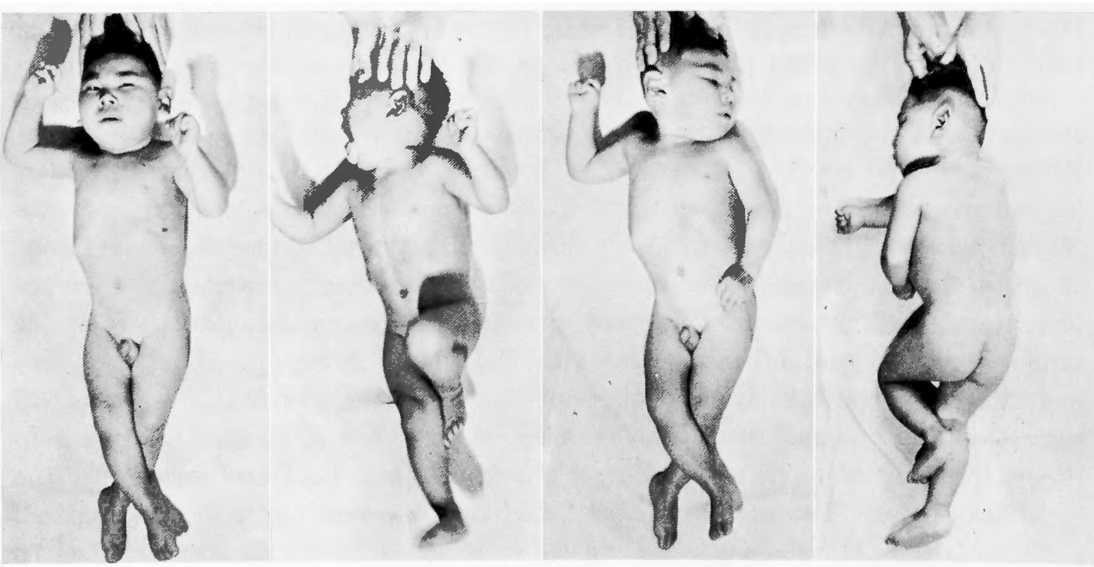
It is the purpose of this study to elucidate the underlying nature of the postures and movements which are exhibited in cerebral palsy of spastic type. Movement, or the ability to propel through space, is characteristic of the biological world. Although the pyramidal tract is universally regarded as being concerned with controlling voluntary movement, all chordates below mammals are able to make adjustments to their respective environments without it. A great number of studies on the true anatomical, physiological, pathological and clinical roles of the pyramidal and extrapyramidal system have been undertaken. As Bieber and Fulton proved, when the precentral motor cortex is bilaterally removed from monkey, the animal is reduced to the thalamic reflex status and voluntary activity of all four limbs is completely abolished. Furthermore, Fulton proved in monkey that, if in one hemisphere as little as 15 to 20 per cent of "agranular" frontal cortex remains intact, the animal ultimately regains some degree of volitional movement in all four limbs. Tower confirmed in monkey that section of the medullary pyramids causes defective initiation and execution of all performance by skeletal musculature with elimination of non-stereotyped components and of all discrete usage of the digits. Foerster also stated that, if area 4 of the cerebral cortex is removed from man, isolated movements of single segments of the extremities can no longer be performed and the movements performed are distinct and typical synergies. The results of these studies revealed that some components of voluntary movement performed in man and monkey also are dependent upon the extrapyramidal system. From the neuroanatomical point of view, Hirasawa divided the extrapyramidal system into five categories; cortical, striopallidal, cerebellar, mesencephalospinal and peripheral extrapyramidal system. These systems may be under the application of the evolutionary principle of levels of function, which implies that headward segments of the brain have become dominant over caudal, and that when higher parts are removed, many activities of lower segments are, after a time, "released" and can then be more readily analyzed. These facts are thought to shed light on the neuropathology of cerebral palsy, long shrouded in ambiguity. In this study, clinical features exhibited in spastic cases of cerebral palsy were examined on the basis of recent neurology, with special reference to the pattern of movement and deformity of the involved extremities. Furthermore, for the purpose of study on neuropathology of cerebral palsy, in the monkeys from which the precentral motor areas were removed, the patterns of posture and movement were observed.

Fig. 1 Typical attitude in the case with low decerebration.

I. Clinical Observation on Posture and Movement in Cerebral Palsy of Spastic Type.

In our clinic, out of 300 cases of cerebral palsy of spastic type, 2 cases with low decerebration and 33 cases with high decerebration were found. In cases with low decerebration, the upper and lower extremities were rigidly extended, assuming the typical decerebrate attitude of KINNEA WILSON (Fig. 1). In this condition, the postural reflexes of MAGNUS and DE KLEYN were difficult to bring out. In cases with high decerebration, when lying supine, the upper extremities assumed a flexed position and the lower extremities were extended (Fig. 2-A), and the tonic neck reflexes (Figs. 2-B and C), the righting reflexes (Fig. 2-D) and the supporting reactions (Figs. 3-A and B) were well demonstrated. In these cases, voluntary movement was completely abolished. From the clinical observations in many cases of cerebral palsy with high



A B C D

Figs. 2-A, B, C and D. Case with high decerebration. A, Typical attitude when lying supine. B, Tonic neck reflex. C, Tonic neck reflex. D, Righting reflex.

A B

Figs. 3-A and B. Supporting reaction.

Table 1 Basic patterns of movement evoked within the upper and lower extremities in the decerebrate state

Upper Extremity						
	Shoulder girdle	Shoulder	Elbow	Forearm	Wrist	Fingers
Flexion	Elevation	Abduction	Flexion	Pronation	Palmar flexion	Flexion
Extension	Depression	Adduction	Extension	Midway position	Dorsiflexion	Extension

Lowe Extremity				
	Hip	Knee	Ankle	Toes
Flexion	Flexion and abduction	Flexion	Dorsiflexion and eversion	Dorsiflexion
Extension	Extension and adduction	Extension	Plantar flexion and inversion	Plantar flexion

decerebration, it was confirmed that the basic patterns of the stereotyped flexor and extensor synergies performed within the respective extremities are those shown in Table 1. Furthermore, the postures and movements of the same pattern were observed in most cases of spastic type in which the postural and righting reflexes were never evoked. In some cases of spastic hemiplegia, the upper extremity was thrust backwards in rigid extension with pronation of the forearm and flexion of the wrist and fingers, and the lower extremity was extended with adduction of the hip and equinovarus of the ankle (Fig. 4). The attitude in this case may be designated the "low decerebrate attitude", because it is identical with that in the case with low decerebration. In contrast, in a severe case of quadriplegia, the upper extremities

Fig. 4 Typical attitude of the upper extremity in the case of spastic hemiplegia of low decerebrate type.

were flexed with abduction of both shoulders and the lower extremities were extended with equinovarus of both ankles (Fig. 15). The attitude in this case may be designated the "high decerebrate attitude", because it is identical with that in the case with high decerebration. In most cases of spastic hemiplegia of high decerebrate type, however, the upper extremity was adducted at the shoulder with flexion of the elbow, wrist and fingers and the lower extremity was extended (Fig. 6). Moreover, in all these cases, voluntary movements of the proximal joints of the upper and lower extremities were somewhat vigorously performed, though those of the distal joints were profoundly affected. These facts suggest that the proximal joints of the involved extremity were released from the frame of the postural reflexes and became capable of independent use of the individual extremity. In some other cases of spastic hemiplegia, the elbow as well as the

Fig. 5 Typical attitude in the case of spastic quadriplegia of high decerebrate type.

Fig. 6 Attitude of the upper extremity in the case of spastic hemiplegia of high decerebrate type. The shoulder is released from the frame of the decerebrate attitude, but the elbow, wrist and fingers are held in the decerebrate attitude.

Fig. 7 Attitude in the case of spastic hemiplegia of high decerebrate type. The elbow as well as the shoulder is released from the frame of the decerebrate attitude, but the forearm is held in pronation and the wrist and fingers in flexion.

A

B

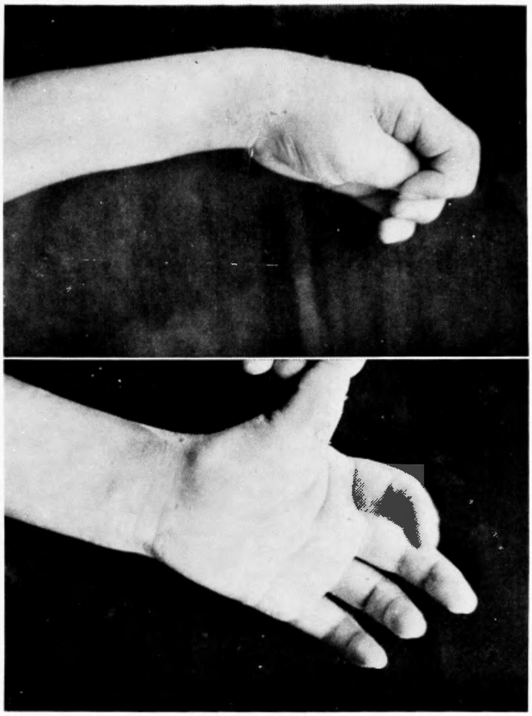


Fig. 8-A and B. In the case of spastic hemiplegia with flexion deformity of the fingers (A), passive extension and abduction of the thumb out of the palm are followed by extensor synergies of the remaining four fingers (B).

shoulder was released from the frame of the decerebrate attitude and was able to execute voluntary movement, though the forearm was held in pronation and the wrist and fingers in rigid flexion (Fig. 7). Moreover, in some cases of spastic hemiplegia with flexion deformity of the distal joints of the upper extremity, as COOPER proved, passive extension and abduction of the thumb out of the palm were followed by extensor synergies of the remaining four fingers (Figs. 8-A and B). Even in the cases with flexion deformity of the fingers in which passive movements of the thumb were never followed by reaction of the remaining fingers, if the wrist and thumb were maintained in extension by plaster, the remaining fingers were also released from the palm within two months and became capable of voluntary movement. In all these cases, however, the movements performed were distinct and typical synergies. The fingers acted together whichever of the latter was moved voluntarily. Frequently, active flexion of the fingers was combined with flexion of the wrist, and active extension of the former with extension of the latter (Figs. 9-A and B). Furthermore, in some of these cases, in the extension phase of synergy of the fingers, mallet-abduction deformities occurred (Figs. 10-A and B). In spastic paraplegia, the lower extremities were strongly extended with adduction of both hips and equinovarus of both ankles, frequently assuming a scissors position when standing (Figs. 11-A and B). Not infrequently, equinovarus of the ankle was combined with flexion of the toes (Fig. 12).

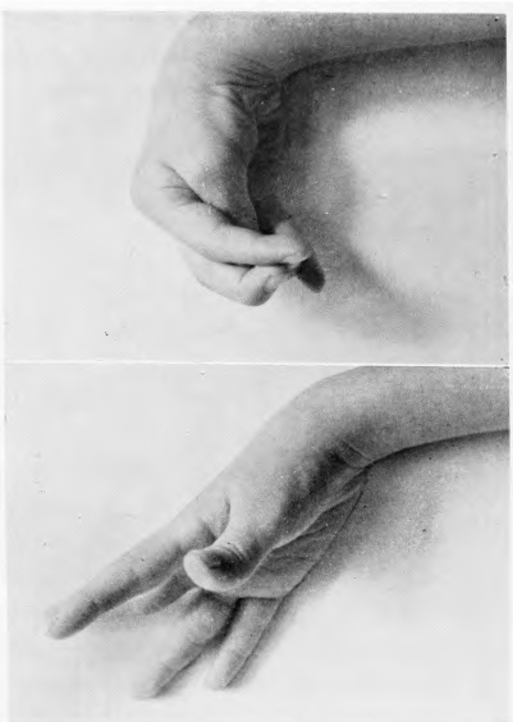
The conclusions reached from these facts are as follows: 1) In cerebral palsy with high decerbration, the patient is reduced virtually to the thalamic reflex status, exhibiting all of responses of MAGNUS and DE KLEYN.

2) In the majority of spastic cases, however, the proximal joints of the involved extremities are detached from the frame of the postural reflexes and become capable of independent use of the individual extremity.

3) In contrast, in most cases of spastic paralysis, the distal joints are held in the decerebrate attitude. The movements which are performed under this circumstance are flexor and extensor synergies.

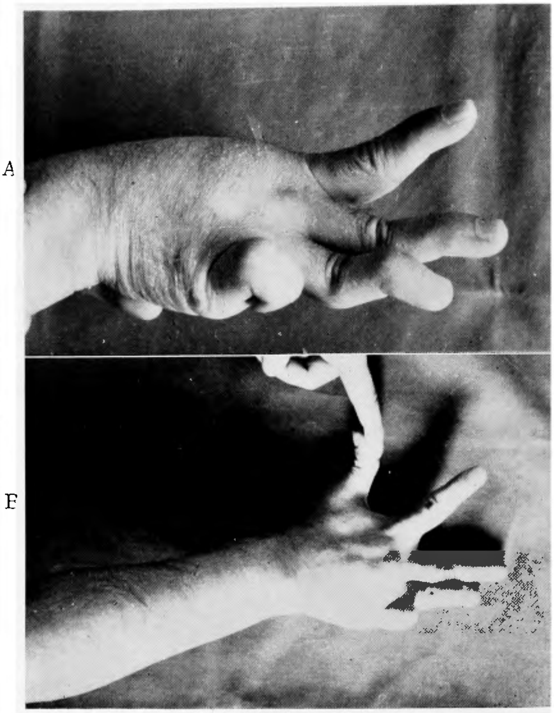
A

B



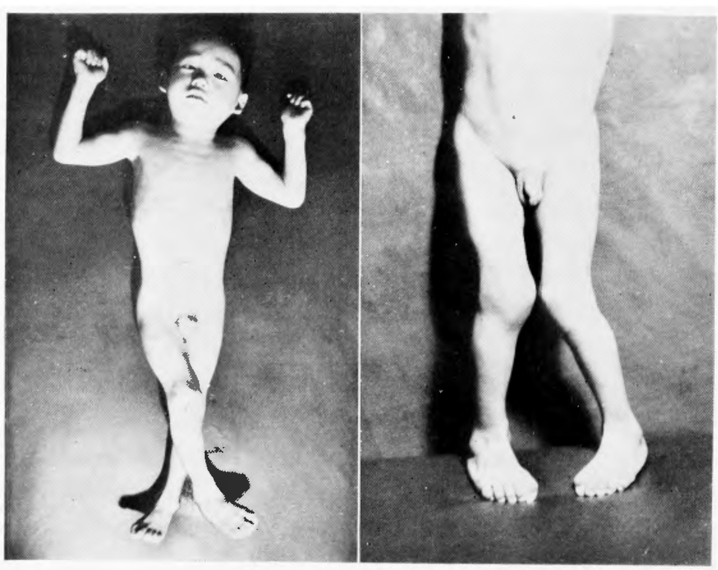
A

B



Figs. 9-A and B. Case of spastic hemiplegia. A, Active flexion of the fingers is combined with flexion of the wrist. B, Active extension of the former with extension of the latter.

Figs. 10-A and B. Case of spastic hemiplegia. In the extension phase of synergy of the fingers, mallet (A) - abduction (B) deformities occur.



A B

Figs. 11-A and B. Case of spastic paraplegia. The lower extremities cross each other (A) and assume a scissors position when standing (B).

II. Ablation of the Precentral Cortex in Monkey

Fig. 12 Case of spastic paraplegia. Equinovarus of the ankle is combined with flexion deformity of the toes.

Method

Macaca cynomologa was used for the experiment. In the first experiment, the precentral motor areas (areas 4 and 6a) were bilaterally removed in fifteen animals. Two or three days after operation, the tonic neck reflexes were well evoked. In this condition, responses elicited in the respective muscles of the upper and lower limbs by rotation of the head were electromyographically examined. In the second experiment, fifteen animals were divided into three equal groups. The motor and premotor areas (areas 4 and 6a) were unilaterally removed in the first group, area 6a in the second and area 4 in the third. In another group of monkeys with prior unilateral ablation of area 4, area 6a or both areas, the second ablation of these respective areas was produced on the opposite side, thus six types of ablation of the precentral motor cortex were established. In these animals, observation on the patterns of posture and movement of the involved limbs and neurological examination were made for two months after operation. In all these expepiments, the precentral cortex was exposed under general anaesthesia with Thiopental Sodium and was cauterized. The respective extents of areas 4 and 6a were cytoarchitectually and also electrophysiologically determined. Moreover, in some cases, microscopic examination of sections of the removed cortex permitted identification of the extent of the cortical area removed.

Result

Experiment I. Basic pattern of the flexor and extensor synergies elicited in the decerebrate monkey

Two or three days after bilateral ablation of areas 4 and 6a, the tonic neck reflexes were well demonstrated. In this condition, responses elicited in the respective muscles of four limbs by rotation of the head were electromyographically examined. The result of this experiment is shown in Table 2. In the decerebrate state, all skeletal muscles of four limbs are divided into two groups: flexor and extensor. The former muscle group is engaged in contracting in flexion-phase and the latter muscle group in extension-phase. Responses elicited in both muscle groups followed the principle of reciprocal innervation. Moreover, in these muscles, the shortening and lengthening reactions of SHERRINGTON were well demonstrated. From these results, it was revealed that the pattern of the flexor and extensor synergies evoked in the decerebrate monkey is identical with that in man with high decerebration, with the exception of the pattern of movement of the toe. In man, the interosseous

Table 2 Muscles to be engaged in contracting in flexion-phase and in extension-phase of the postural reflex in monkey.

Upper Extremity

Extensor	Flexor
Shoulder	
M. subscapularis	M. levator scapulae
M. pectoralis major	M. trapezius
M. teres major	M. deltoideus
	M. supraspinatus
	M. infraspinatus
	M. teres minor
Upper arm	
M. triceps brachii	M. biceps brachii
	M. coracobrachialis
	M. brachialis
Forearm	
M. anconeus	M. supinator
M. extensor carpi radialis longus	M. pronator teres
M. extensor carpi radialis brevis	M. pronator quadratus
M. extensor carpi ulnaris	M. brachioradialis
M. extensor digitorum communis	M. flexor carpi radialis
M. extensor pollicis longus	M. flexor carpi ulnaris
M. extensor pollicis brevis	M. palmaris longus
M. abductor pollicis longus	M. flexor digitorum profundus
M. extensor indicis proprius	M. flexor pollicis longus
M. extensor digiti minimi proprius	M. flexor digitorum superficialis
Hand	
M. abductor pollicis brevis	M. palmaris brevis
M. abductor digiti minimi	M. flexor pollicis brevis
Mm. interossei dorsales	M. adductor pollicis
Mm. lumbricales	M. opponens pollicis
	M. flexor digiti minimi brevis
	M. opponens digiti minimi
	Mm. interossei palmares

Lower Extremity

Extensor	Flexor
Hip	
M. glutaeus maximus	M. psoas major
	M. psoas minor
	M. iliacus
	M. glutaeus medius
	M. glutaeus minimus
	M. piriformis
	M. obturatorius internus
	M. obturatorius externus
	M. gemellus superior
	M. gemellus inferior
	M. quadratus femoris
	M. tensor fasciae latae
Thigh	
M. quadriceps femoris	M. sartorius
M. adductor longus	M. pectineus
M. adductor brevis	M. gracilis
M. adductor magnus	M. semitendinosus

	M. semimembranosus
	M. biceps femoris
Leg	
M. gastrocnemius	M. tibialis anterior
M. soleus	M. peroneus longus
M. tibialis posterior	M. peroneus brevis
M. flexor digitorum longus	M. extensor digitorum longus
M. flexor hallucis longus	M. extensor hallucis longus
Foot	
M. extensor digitorum brevis	M. quadratus plantae
M. extensor hallucis brevis	M. flexor digitorum brevis
M. abductor hallucis	M. flexor hallucis brevis
M. abductor digiti minimi	M. flexor digiti minimi brevis
Mm. interossei dorsales	M. adductor hallucis
Mm. lumbricales	M. opponens digiti minimi
	Mm. interossei plantares

and lumbrical muscles flex the first phalanx of the toe without extension of the distal two, whereas, in monkey, they flex the first phalanx with extension of the distal two, as in the hand. From this experiment, several noteworthy results were obtained :

1) In the shoulder, the abductors belong to the extensor group.

2) In the forearm, the pronators as well as the supinator are included among the flexor group.

3) In the hand, the lumbricales and abductors, such as the abductor pollicis brevis, abductor digiti minimi and interossei dorsales, belong to the extensor group, whereas the opponens pollicis, opponens digiti minimi and adductors, such as the adductor pollicis and interossei palmares, to the flexor group.

4) In the hip, the abductors and external rotators belong to the flexor group.

5) In the leg, the flexor digitorum longus, flexor hallucis longus and tibialis posterior, as well as the triceps surae, belong to the extensor group.

6) In the foot, the short extensors, lumbricales and abductors, such as the abductor hallucis, abductor digiti minimi and interossei dorsales, belong to the extensor group, whereas the opponens digiti minimi, short flexors and adductors, such as the adductor hallucis and interossei plantares, to the flexor group.

Experiment II. Posture and movement in monkey with a lesion of the precentral motor cortex

1. Unilateral ablation of areas 4 and 6a

When areas 4 and 6a were unilaterally removed, the profound paralysis of the contralateral limbs resulted. The animal remained in a lateral position with all limbs in semiflexion for two or three days after operation. The tonic neck and labyrinthine reflexes were well evoked in this state and disappeared thereafter with the return of voluntary movements at the neck and proximal joints of the affected limbs. The righting reflexes were elicited for three to ten weeks after operation. Within a week after operation, the animal became capable of crouching and began to strive to stand without result. Three to four weeks after operation, active movements reappeared at the shoulder, hip and knee, which allowed the animal to use the limbs in rhythmic progression. However, active movements of the distal joints, especially of the fingers, were never regained. The affected upper and lower limbs were held in a semiflexed position and exhibited an increased resistance to passive manipulation. In this condition, passive movements of each joint of the

A

Fig.13-A Monkey with a unilateral lesion of areas 4 and 6 a. Passive abduction of the shoulder is followed by flexor synergies of the elbow and fingers.

B

Fig. 13-B Same monkey. Passive forward elevation of the shoulder is followed by extensor synergies of the elbow, wrist and fingers.

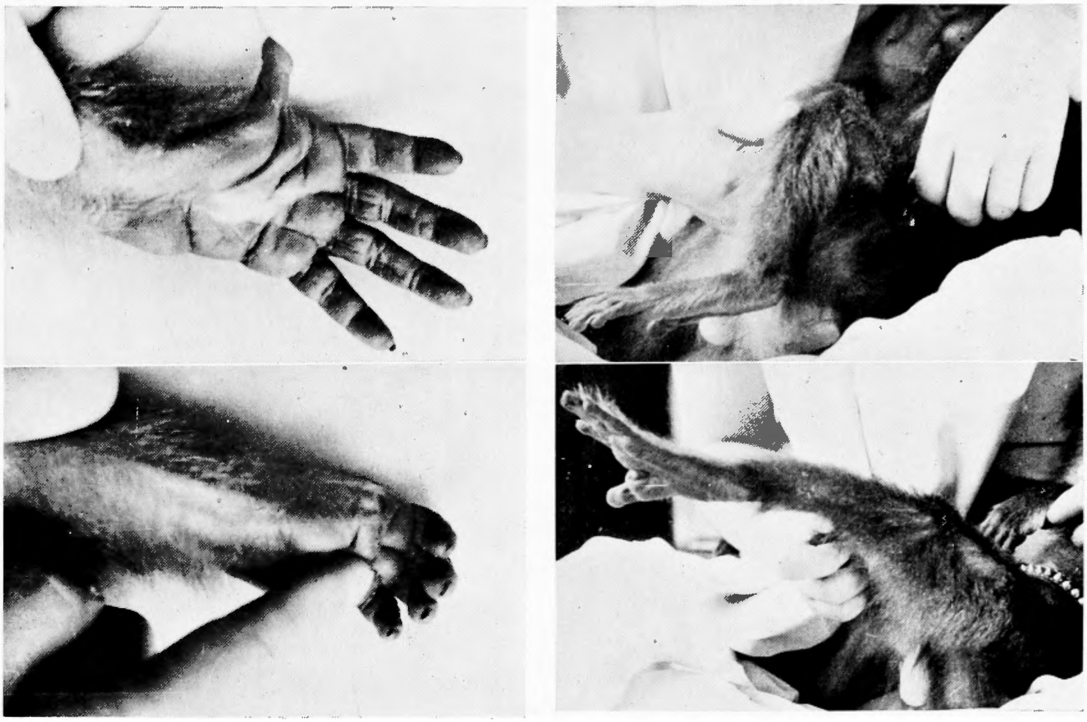
C

Fig. 13-C Same monkey. Passive flexion of the elbow is followed by flexor synergy of the wrist.

D

Fig. 13-D Passive extension of the elbow is followed by extensor synergy of the wrist.

E G



F H

Fig. 13-E. Same monkey. Passive extension and abduction of the thumb out of the palm are followed by extensor synergies of the remaining four fingers.

Fig. 13-F. Same monkey. Passive flexion and adduction of the thumb are followed by flexor synergies of the remaining four fingers.

Fig. 13-G. Same monkey. Passive flexion of the hip is followed by flexor synergies of the knee, ankle and toes.

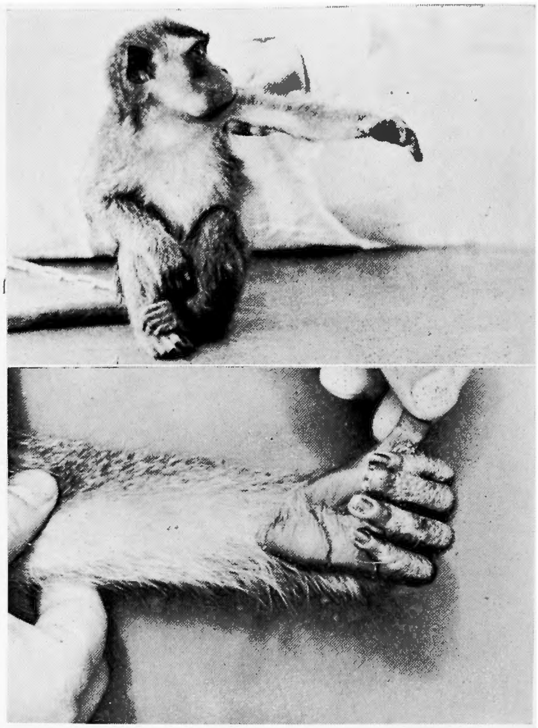
Fig. 13-H. Same monkey. Passive extension of the hip is followed by extensor synergies of the knee, ankle and toes.

involved limbs were followed by flexor and extensor synergies of the adjacent joints. If the shoulder was to be passively abducted, the elbow, wrist and fingers were also automatically flexed, and if the former was to be passively elevated forward, the latter were also extended (Figs. 13-A and B). If the elbow was to be flexed, the wrist was also flexed, and if the former was to be passively extended, the latter was also extended (Figs. 13-C and D). Furthermore, passive abduction and extension of the thumb out of the palm evoked extension of the remaining four fingers, and passive adduction and flexion of the former evoked flexion of the latter (Figs. 13-E and F). Moreover, the flexor and extensor synergies were observed in the lower limb. Passive flexion of the hip was followed by flexor synergies of the knee, ankle and toes, and passive extension of the former was followed by extensor synergies of the latter (Fi. gs13-G and H). Passive extension and abduction of the great toe were followed by extensor synergies of the remaining four toes, and passive flexion and adduction of the former were followed by flexor synergies of the latter (Figs. 13-I and J). These stereotyped flexor and extensor synergies were

I

J

A



B

Fig. 13-I. Same monkey. Passive extendion and abduction of the great toe are followed by extensor synergies of the remaining four toes.
Fig. 13-J. Same monkey. Passive flexion and adduction of the great toe are followed by flexor synergies of the remaining four toes.

Fig. 14-A and B. Monkey from which area 6a is unilaterally removed. The elbow is moved freely with shoulder fixed in abduction (A) and passive extension and abduction of the thumb are never followed by extensor synergies of the remaining four fingers (B).

identical in pattern with those induced by rotation of the neck in the decerebrate state. These facts prove that in this condition the proximal joints of the involved limbs are released from the frame of general synergies and become capable of independent use of the individual limb: however, the distal joints still remain in the frame of synergies which are evoked by movements of the proximal joints instead of the neck.

2. Unilateral ablation of area 6a

An unilateral ablation of area 6a was followed by transient weakness of the contralateral limbs. Two days after operation, voluntary movements reappeared at the proximal joints of the involved limbs, and the animal became capable of walking, though awkward. At the end of the first week, its gross motor performance was almost normal. The animal was able to carry out deep-rooted habits such as grooming of hairy surfaces. The postural reflexes of Magnus and de Kleyn were not demonstrated, whereas the righting reflexes were elicited on the day following operation and disappeared thereafter. In this condition, passive movements of each joint of the involved limbs were never followed by flexor and extensor synergies of the adjacent joints. The elbow was moved freely with the shoulder fixed in abduction (Fig. 14-A). Passive abduction and extension of the thumb out of the palm were never followed by extensor synergies of the remaining four fingers (Fig. 14-B).

3. Unilateral ablation of area 4

When the motor area was unilaterally removed from monkey, a profound paresis resulted affecting all muscles of the entire contralateral upper and lower limbs. The tonic neck reflexes were evoked in three animals out of five on the day following operation and disappeared thereafter. They were not elicited in remaining two. The righting reflexes were demonstrated in all animals for one or two weeks after operation and disappeared thereafter with the return of voluntary movements at the proximal joints of the affected limbs. Within one to two weeks, purposeful movements reappeared at the proximal joints, which allowed the animal to use the limbs in rhythmic progression. Four weeks after operation, voluntary movements of the fingers were awkwardly executed. However, dexterity of finer movements was never regained. The affected upper and lower limbs were held in a semiflexed position and exhibited no increased resistance to passive manipulation. In this condition, passive movements of each joint of the involved limbs were followed by the flexor and extensor synergies of the adjacent joints which were identical in pattern with those in the monkey from which areas 4 and 6a were unilatarally removed. If the shoulder was to be passively abducted, the elbow, wrist and fingers were also automatically flexed, and passive elevation of the former caused extension of the latter. Passive extension and abduction of the thumb out of the palm were followed by extension of the remaining four fingers. If the hip were to be passively extended, the knee, ankle and toes were also extended, and if the former were to be flexed, the latter were also flexed.

4. Bilateral ablation of the precentral motor areas

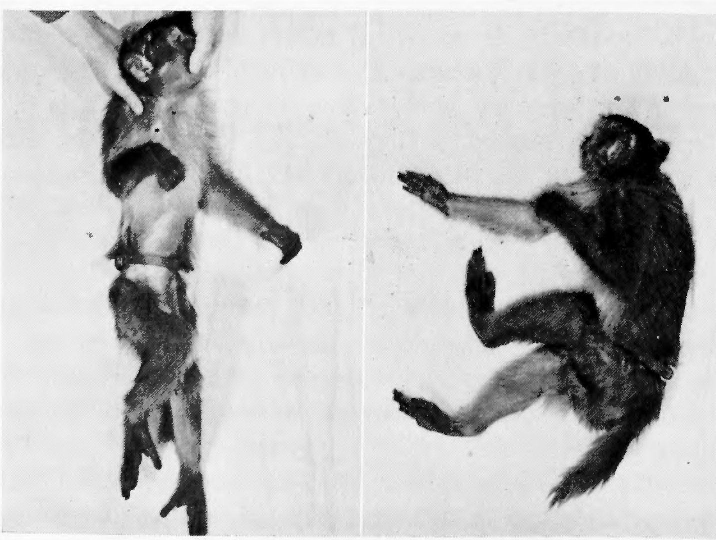
In another group of monkeys, area 4, area 6a or both areas were removed from both hemispheres in six types of combination, as shown in Table 3. In all these cases, the patterns of movement performed were examined for six weeks after operation. The results of these experiments are briefly summarized in Table 3. When areas 4 and 6a were bilaterally removed, the animal was reduced virtually to the thalamic reflex status, exhibiting all of the thalamic patterns of response of MAGNUS (Figs. 15-A and B).

In this state, passive movements of each joint of four limbs also caused the stereotyped flexor and extensor synergies of the adjacent joints which were identical in pattern with those induced by changing the position of the head in relation to the body. One week after operation, four limbs were held in the decerebrate attitude and all reflexes became difficult to bring out. However, if area 6a of one hemisphere remained intact, as in Case 5, the tonic neck reflexes disappeared within several days after operation and then some degree of volitional movement reappeared at the proximal joints of all four limbs. Nevertheless, passive movements of each joint of four limbs were followed by the flexor and extensor synergies of the adjacent joints which were identical in sequence with those in the decerebrate state.

Table 3 Changes of the postural and righting reflexes and movement following motor and premotor cortex lesion

Case No.	Cortical areas removed from right(r) and left(l) hemisphere	Symptoms developing in the contralateral limbs after cortical lesions																							
		1 day				3 days				1 week				3 weeks				5 weeks				6 weeks			
		M	R	V	S	M	R	V	S	M	R	V	S	M	R	V	S	M	R	V	S	M	R	V	S
1	r 6 a	–	–	P	–	–	–	P	–	–	–	P D	–	–	–	P D	–	–	–	P D	–	–	–	P D	–
	l 6 a	–	–	P	–	–	–	P	–	–	–	P D	–	–	–	P D	–	–	–	P D	–	–	–	P D	–
2	r 6 a	–	–	P	–	–	–	P	–	–	–	P D	–	–	–	P D	–	–	–	P D	–	–	–	P D	–
	l 4	+	+	–	+	–	+	–	+	–	+	P	+	–	–	P	⧺	–	–	P	⧺	–	–	P	⧺
3	r 4	+	+	–	+	–	+	–	+	–	+	P	+	–	–	P	⧺	–	–	P	⧺	–	–	P	⧺
	l 4	+	+	–	+	–	+	–	+	–	+	P	+	–	–	P	⧺	–	–	P	⧺	–	–	P	⧺
4	r 6 a	–	–	P	–	–	–	P	–	–	–	P D	–	–	–	P D	–	–	–	P D	–	–	–	P D	–
	l 4 and 6 a	+	+	–	+	+	±	–	+	–	+	–	⧺	–	+	P	⧺	–	+	P	⧺	–	+	P	⧺
5	r 4	+	+	–	+	+	±	–	+	–	+	P	⧺	–	–	P	⧺	–	–	P	⧺	–	–	P	⧺
	l 4 and 6 a	+	+	–	+	+	+	–	+	–	+	–	⧺	–	+	P	⧺	–	+	P	⧺	–	+	P	⧺
6	r 4 and 6 a	+	+	–	+	+	+	–	+	+	+	–	⧺	The rigidity was so intense that the											
	l 4 and 6 a	+	+	–	+	+	+	–	+	+	+	–	⧺	reflexes became difficult to bring out.											

M-Reflexes of Magnus and de Kleyn, R-Righting reflexes.
V-Voluntary movement of the proximal (P) and distal (D) joints.
S-Synergies evoked by passive movements of joint of the involved limb; (+)-synergies of the proximal joints, (⧺)-synergies of all joints of the involved limb.



A B

Figs. 15-A and B. Monkey from which areas 4 and 6 a are bilaterally removed. Tonic neck reflex (A) and rgihting reflex (B).

Furthermore, when area 4 was uni- or bilaterally removed, as in Cases 2 and 3, the tonic neck reflexes were demonstrated for one or two days and disappeared before the return of voluntary activity at the proximal joints. However, in this condition, passive movements of each joint of the involved limbs well evoked the flexor and extensor synergies of the adjacent joints, as in the case mentioned above. In contrast, in the monkey from which area 6a was bilaterally removed, the postural reflexes as well as righting reflexes were not demonstrated. Moreover, passive movements of each joint were never followed by synergy of the adjacent joints during the course of the experiment.

Discussion

The effect of ablation of the precentral motor areas has been studied by a number of investigators who used all members of the primate series including man. In particular, this has been much discussed by FOERSTER and FULTON. In the present study, the mechanism involved in the performance of movement in the monkey with a lesion of the precentral motor cortex was analyzed. In the monkey with bilateral decortication in which the postural reflexes were demonstrated, passive movements of each joint were followed by the distinct stereotyped flexor and extensor synergies of the adjacent joints which were identical in sequence with those induced by changing the position of the head in relation to the body. These synergies also are the postural reflexes mediated by the brain stem. As FULTON proved, if area 6a of one hemisphere remained intact, the tonic neck reflexes disappeared with the return of voluntary activity at the proximal joints. Nevertheless, in this condition, passive movements of each joint still evoked the flexor and extensor synergies of the adjacent joints. These synergies may also be the postural reflexes. The synergies of the same pattern were well demonstrated in the limb which was lacking the control provided by area 4, however, they were never elicited in the limb under the control of area 4.

The conclusions reached from these experiments are as follows:

1) The functions of the cortical extrapyramidal motor areas enable the neck and proximal joints of all four limbs to execute individual voluntary movements detached from the frame of the postural reflexes mediated by the brain stem. 2) However, the functions of these extrapyramidal cortical areas are unable to detach the distal joints from the frame of synergies which are evoked by movements of the proximal joints instead of the neck. 3) In this condition, the affected joints are held in the decerebrate attitude.

These findings observed in the monkeys with a lesion of the precentral motor cortex bear a remarkable resembrance to the clinical features exhibited in cerebral palsy of spastic type. COURVILLE's series of 127 cases of cerebral palsy in which the significant lesions were verified by postmortem examination suggests that the clinical features exhibited in cerebral palsy of spastic type are caused by complete or incomplete lesion of both precentral motor cortices or both frontal lobes. From these facts, it is presumed that the results of the present experiments elucidate the underlying nature of the clinical features exhibited in spastic paralysis. Spastic paralysis in which the postural and righting reflexes are demonstrated may result from bilateral lesion of the precentral motor cortex or the frontal lobe. Spastic paralysis in which the typical postural reflexes are not evoked and active movements of the proximal joints are somewhat vigorously performed may be theresult of incomplete decerebration. In the latter case, it is thought that the voluntary activity of the proximal joints is dependent upon the function of the undamaged cortical extrapyramidal area and the flexor and extensor synergies of the fingers are the postural reflexes which are mediated by the brain stem.

Furthermore, in most cases of spastic paralysis, the involved extremities are held in the decerebrate attitude due to disturbance of active movement, and frequently results in fixed contracture in such attitude. In a severe case of high decerebrate type, the upper extremity is held in flexion with abduction of the shoulder and the lower extremity is held in extension with adduction of the hip and equinovarus of the ankle, as shown in Figs. 2-A and 5. The muscles to be engaged in contracting in the flexion phase of synergy of the upper extremity and those in the extension phase of synergy of the lower extremity are shown in Table 2. The shoulder is held in abduction by the deltoideus and supraspinatus, and the elbow in flexion by all flexors of this joint. The forearm is held in pronation by the pronator teres and quadratus. Though the supinator as well as the pronators contracts in the flexion phase, the latter are predominant over the former. The wrist is held in flexion by the long flexors of the fingers as well as the flexors of the wrist. The thumb is held in flexion-adduction-opposition by the flexor longus and brevis, adductor and opponens, and the other four fingers in flexion-adduction by the long flexors and interossei palmares. Moreover, in the extension phase of synergy of the fingers, mallet-abduction deformities occur due to contraction of the interossei dorsales and lumbricales which belong to the extensor group, as shown in Figs. 10-A and B. The hip is held in extension-adduction by the glutaeus maximus and adductors, and the knee in extension by the quadriceps femoris. The ankle is held in equinovarus by the triceps surae and tibialis posterior, and the toes in plantar flexion by the long flexors, interossei dorsales and lumbricales. Frequently, the lower extremities cross each other due to extension-adduction deforminites of both hips and assume a scissors position when standing, as shown in Figs. 11-A and B.

Summary

1. In 300 cases of cerebral palsy of spastic type, the patterns of movement and deformity of the involved extremities were clinically examined.

2. The conclusions reached from clinical observation are as follows: a) In cerebral palsy with high decerebration, the patient is reduced virtually to the thalamic reflex status, exhibiting all of responses of Magnus and de Kleyn. b) In the majority of spastic cases, however, the proximal joints of the involved extremities are detached from the frame of the postural reflexes and become capable of independent use of the individual extremity. c) In contrast, in most cases of spastic paralysis, the distal joints are held in the decerebrate attitude. The movements which are performed under this circum stance are flexor and extensor synergies.

3. In the monkeys (macaca cynomologa) from which the precentral motor areas were uni- or bilaterally removed, the patterns of movement performed in the involved limbs were analyzed.

4. In the monkey with bilateral decortication in which the tonic neck reflexes were demonstrated, responses elicited in the respective muscles of four limbs by rotation of the head were electromyographically examined.

5. In the monkey with bilateral decortication in which the tonic neck reflexes were demonstrated, passive movements of each joint were followed by distinct stereotyped flexor and extensor synergies of the adjacent joints. These synergies also are the postural reflexes.

6. When areas 4 and 6a of one hemisphere and area 4 of the opposite were removed from monkey, the tonic neck reflexes were evoked for several days and disappeared thereafter with the return of voluntary movements at the neck and proximal joints. In this condition, passive movements of each joint evoked the flexor and extensor synergies of the adjacant joints which were identical in sequence with those in the decerebrate state. Furthermore, the synergies of the same pattern were well demonstrated in the limb which was lacking the control provided by area 4, however, they were never elicited in the limb under the control of area 4.

7. The conclusions reached from these experiments are as follows: a) The functions of the cortical extrapyramidal motor areas enable the neck and proximal joints of all four limbs to execute isolated voluntary movements detached from the frame of the postural reflexes mediated by the brain stem. b) However, the functions of these extrapyramidal cortical areas are unable to detach the distal joints from the frame of synergies which are evoked by movements of the proximal joints instead of the neck. c) In this condition, the affected joints are held in the decerebrate attitude.

8. On the basis of the results of these experiments, the underlying nature of the clinical features exhibited in cerebral palsy of spastic type was considered.

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和文抄録

痙性麻痺に於ける姿勢と運動の臨床的及び実験的研究

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1）300例の痙性麻痺患者に就いて4肢の運動と変形の型式の臨床観察を行つた．

2）臨床観察から得られた結論は次の通りである．a）高位除脳症例では，患者は視床反射の状態になりMagnus and de Kleynの姿勢反射がすべて証明される．b）然し，痙性麻痺の大部分の症例では，罹患肢の中枢側の関節に随意運動能力が回復し，各肢の単独の随意運動が出来る様になる．c）之に反して，罹患肢の末梢関節は依然として除脳肢位に固定されており，又この様な状態に於て行われる運動は屈伸協同運動である．

3）かにくい猿の両側大脳皮質中心前領（分野4及び6a）を種々の組合せに於て破壊し，罹患肢の運動型式を観察した．

4）両側除皮質猿の緊張性頸反射に於いて4肢の各筋に誘発される反応を筋電計を用いて調査した．その成績は Table 2に示した通りである．この成績は足指の運動を例外とすれば，人類の緊張性頸反射について観察した成績とよく一致する．人類の緊張性頸反射に於ける4肢の屈伸協同運動型式は Table 1に示した通りである．

5）両側除皮質猿では，頭の回転によつて4肢に屈伸協同運動がおこるだけでなく，又4肢の各関節の他動運動によつても隣接関節に同一型式の屈伸協同運動がおこる．この反射運動も亦姿勢反射である．

6）一側大脳皮質の分野4と6a，他側の分野4を破壊した場合には，術後数日間は緊張性頸反射が証明されるが，その後，頸と4肢の中枢側の関節に随意運動が回復すると共に，消失する．この様な状態に於ても，各関節の他動運動を行うと隣接関係に除脳猿に於けると同一型式の屈伸協同運動が起る．この様な屈伸協同運動は分野4の支配を失つた上下肢には常に証明されるが，分野4の支配下にある上下肢には決して証明されない．

7）以上の実験成績から次の様な結論を得た．a）大脳皮質錐体外路領域の機能によつて，頸と4肢の中枢側の関節は姿勢反射の枠から外され，随意運動を行う様になる．b）然し，末梢関節は皮質錐体外路の機能によつて姿勢反射の枠から外されることはない．c）この様な状態に於いては，罹患肢は除脳肢位に保持されている．

8）以上の実験成績に基いて，痙性麻痺症例の臨床像の意義について考察を行なつた．